RIO NUEVO LANDFILL STABILIZATION PROJECT
INTERIM TECHNICAL REPORT
ON THE NEARMONT SITE

Prepared for:

CITY OF TUCSON
ENVIRONMENTAL MANAGEMENT OFFICE
P.O. Box 27210
Tucson, Arizona 85726-7210

Prepared by:

HYDRO GEO CHEM, INC.
51 W. Wetmore, Suite 101
Tucson, Arizona 85705-1678

December 20, 2001

HYDRO GEO CHEM, INC.
Environmental Science & Technology

December 20, 2001

Karen Masbruch
Director, Environmental Management
City of Tucson
P.O. Box 27210
Tucson, Arizona 85726-7210

Re: Interim Technical Report on the Nearmont Site

Dear Ms. Masbruch,

The Rio Nuevo Landfill stabilization pilot test at the Nearmont Landfill began operation approximately five months ago. Before operation began, water was applied to the site starting June 19, 2001. Air circulation began on July 24, 2001. Since July 24, air circulation has been operated for a total of 82 days. The Phase II Pilot Test Work Plan, Rio Nuevo Landfill Stabilization Project (Hydro Geo Chem, Inc. [HGC], 2001[1]) describes the operating and monitoring procedures for the pilot test.

Field data indicate that the pilot test is very successful at accelerating refuse degradation. Nearly one foot of land settlement due to the reduction in refuse volume has been measured after five months of operation. A summary of pilot test results, conclusions, and recommendations based on data collected to date is presented below. Details of operating procedures, evaluation methods, and a more detailed discussion will be provided in a final report. A site map is shown on Figure 1.

51 West Wetmore, Suite 101 Tucson, Arizona 85705 1678 HGC 520.293.1500 520.293.1550 Fax 800.727.5547 Toll Free

---

[1]HGC. 2001. Addendum II Congress Landfill Stabilization Pilot Test Conceptual Design Addendum II to the Phase II Pilot Test Work Plan. July 2001.

Air Circulation

Figure 2 shows the injection and extraction rates for the first five months of operation of the Nearmont pilot test. During the first month, air was injected at a rate of approximately 300 cubic foot per minute (cfm) and extracted at approximately 400 cfm. Preliminary field data indicated that these flow rates resulted in temperature increases outside the test plot that approached the upper limit of the operating temperature that was proposed in the work plan. As a result, the flow rates were reduced to 50 cfm for injection and 100 cfm for extraction. The monitoring results indicate the reduced flow rates maintain oxygen concentrations at 5 to 12% by volume in the refuse. Starting in the middle of October, an alternating air flow pattern was used to control temperatures.

Water Application

The Nearmont Landfill has a thick soil cover consisting of eight to ten feet of high clay-content materials. This thick cover slows water delivery to the refuse. Water application to the test plot has also been limited by a temporary aquifer protection permit (APP) issued by the Arizona Department of Water Quality (ADEQ). The temporary APP limits the total application of water at the site to 400,000 gallons. To date, less than half of this 400,000 gallons has been added to the site. The APP also states the following:"The system shall be monitored and operations adjusted to ensure the pilot does not promote the generation of leachate in quantities that will be released to the vadose zone. The project shall be operated such that liquids do not rise above the bottom 1.5 feet of sump casing in any well."

Four methods are currently being used to monitor subsurface moisture movement: 1) gypsum blocks, 2) lysimeters, 3) time domain reflectometry (TDR), and 4) ground penetrating radar (GPR). As proposed in the Phase I Report (HGC, 2000[2]), GPR is the most successful method for monitoring subsurface moisture at this site. Figure 3 shows results from GPR profiling at MPN-03 and MPN-04. These results are typical of results from other locations. The GPR results indicate that, despite the limitations on water delivery, moisture contents in the refuse have been increased above background levels, but they have not reached the optimum level stated in the work plan (55% by weight). Moisture contents have, however, reached the lower limit of the optimum moisture content range (40-70 % by weight) recommended for aerobic degradation. Higher degradation rates may be achieved if the water content is increased to the higher end of the optimal range. As a result, the water application rate was increased on November 28, 2001 in an attempt to increase moisture content and achieve faster degradation rates at Nearmont.

Temperature

Temperature is a key indicator of biodegradation and is therefore monitored continually at the site. Figure 4 shows temperature data at 20 feet below ground surface in selected wells both inside and outside the test plot. In general, higher temperatures mean faster biodegradation rates, until a temperature of approximately 180°F is reached. Above 180°F, biological activity and metabolic heat evolution slow significantly (Miller, 1996[3]) because most microorganisms cannot survive at such high temperatures. Many scientists report optimal decomposition rates for the surface composting industry to occur between 110°F and 160°F. In commercial surface composting practices with large-scale field operations, temperatures around 180°F are commonly observed (Miller, 1996). During the five months of pilot test operation, temperatures in the test plot approached 160°F a few days after air circulation began. Although the

[2]HGC. 2000. Phase I Field Investigation Results, Rio Nuevo Landfill Stabilization Project, Tucson, Arizona. August 2000.

[3]Miller, F.C. 1996. "Composting of Municipal Solid Waste and its Components" in *Microbiology of Solid Waste*, Palmisano, A.C. and Barlaz, M.A, eds. CRC Press, New York, NY.

temperatures at a few locations approached 160°F, they were much lower (100 to 140 °F) at most monitoring locations.

Temperature data clearly indicate that aerobic degradation is occurring in the refuse. Without control measures such as the alternating flow patterns described previously, temperatures at a few places would have exceeded 160°F, the maximum operating temperature proposed in the work plan (HGC, 2001). The optimal temperature range needed to establish optimal degradation rates has still not been determined from this pilot test. Hydro Geo Chem believes that if the operating temperature can be increased to 180°F, there will be enough flexibility in operating the system to allow optimal temperatures and therefore optimal degradation rates to be determined.

Landfill Gas Monitoring

Concentrations of methane (CH_4), carbon dioxide (CO_2), oxygen (O_2) and carbon monoxide (CO) have been monitored continually since before the start of air circulation. Figure 5 presents typical soil gas results from one of the extraction wells. Before the start of air circulation, oxygen levels were low, carbon dioxide levels were intermediate, and methane levels were high. After air circulation began, methane levels decreased significantly. At the same time, oxygen and carbon dioxide levels increased. The oxygen concentrations approached 21%, indicating aerobic conditions were achieved inside the test plot. The higher carbon dioxide concentrations were a result of the increased bioactivity.

Carbon monoxide data are not presented in Figure 5 because there is evidence that the CO concentrations reported by the automatic monitoring system do not represent actual subsurface concentrations of this compound. Comparison of field results to laboratory results indicates that field instruments were providing false positives for CO. CO concentrations were being measured because a dramatic increase in this gas can be an indication of a subsurface fire. Starting in October, soil gas samples were collected twice a week for two weeks, then once a week for two weeks, and they continue to be collected once every two weeks. The samples are sent to an analytical laboratory for analysis of fixed gas (O_2, CO_2, CO, and CH_4) concentrations. To date, no CO has been detected in any of the laboratory samples despite elevated concentrations that have been measured by field instruments.

Surface Settlement

Land surface settlement is also an indicator that refuse is being degraded. Under anaerobic conditions, landfill settlement occurs at a rate of approximately one inch per year for most landfills (McBean et al, 1995[4]). Figure 6 shows the results of three surface elevation surveys conducted since the start of air circulation. After 82 days of air circulation, an average settlement of ten inches (0.72 ft) has been measured inside the test plot. Measurable settlement is also observed over an area approximately 75 ft in radius, which is seven times larger than the area of the test plot. The total volume decrease inside the test plot is 1,800 ft^3. If the area outside the test plot is also considered, the volume reduction is more than 5,000 ft^3. The settlement measured to date represents approximately 4% of the total landfill thickness (20 ft). Based on the settlement data and a refuse density of 1200 pounds per $yard^3$ (lb/yd^3), an average of 1,000 lbs per day of refuse has been degraded and removed from the test plot. The final settlement could be as high as 10% of the total refuse thickness, or approximately two feet.

Biodegradation Rates

Based on the field monitoring results, approximately 80,000 pounds (lbs) of refuse have been degraded to date. Assuming a methane generation rate of 5 ft^3 per pound of 100% degradable refuse, this mass of refuse could generate 400,000 ft^3 of methane if it degraded under anaerobic conditions.

---

[4]McBean, E.A., Rovers, F.A., and Farquhar, G.J. 1995. *Solid Waste Landfill Engineering and Design.* Prentice Hall PTR, Upper Saddle River, NJ.

Calculations also show that approximately 46% of the degradable material in the 50 ft by 50 ft test plot has been degraded so far. The resulting refuse degradation rate is estimated at 1,000 lbs per day, which corresponds to a first order degradation rate of 0.006/day. Using this degradation rate, the estimated time for stabilization of 99% of the refuse at Nearmont is 768 days (2.1 years). Degradation rates reported for optimized composting and laboratory studies are much faster, between 0.024/day and 0.18/day (Bernreuter and Stessel, 1999[5]), than that estimated for Nearmont. The degradation rate measured at Nearmont is still approximately 100 times faster than rates reported for anaerobic degradation at arid landfills (2% per year or 0.00005 per day). If operating conditions at Nearmont were further optimized, for example by increasing moisture content and temperature, then faster rates may be achieved and the time required for refuse stabilization at the Nearmont Landfill would be reduced.

Soil Gas and Water Sample Collection

Soil gas, condensate, and groundwater samples have been collected for laboratory analysis. No compounds have been detected in these samples that are cause for environmental concern. Only trace amounts of VOCs and metals have been detected in groundwater samples collected from site wells, and a trace amount of VOCs has been detected in the soil gas samples. These compounds were initially detected during baseline sampling conducted before the pilot test began and their concentrations have not increased during pilot test operation. Results of the water samples are reported to ADEQ on a quarterly basis.

Conclusions and Recommendations

Based on approximately five months of pilot test operation (82 days of air circulation), the following conclusions can be made:

---

[5]Bernreuter, J.C. and Stessel, R.I. 1999. A review of biocell research and technology. Columbia University.

- First order degradation rates are between 0.005 and 0.006 per day, based on calculations using land surface settlement, heat generation, and CO_2 production. Approximately 23 ft^3 (1,000 lbs) of degradable material has been removed from the site per day.

- Based on the degradation rates calculated for the site, it will take approximately 380 to 460 days to reach 90% completion and 768 to 921 days for 99% completion.

- The water content of the refuse has been increased to the lower end of the optimal range, despite limitations in water application caused by the cover soil and the APP. It is possible that degradation rates would be increased if more water was added to bring the moisture content toward the higher end of the optimal range.

- Temperatures in some areas reached 160°F, the maximum operating temperature proposed for this project. In other areas, temperatures are still low. If the maximum operating temperature was increased to 180°F, there would be more flexibility when operating the system. This flexibility would allow determination of the optimal temperature range needed to achieve optimal degradation rates.

- Field observations and laboratory CO measurements do not indicate subsurface fire at the site, even though refuse temperatures in some areas have reached 160°F.

- The CO data collected by the automatic monitoring system, which is equipped with an electrochemical sensor, is not reliable. CO measurements will rely on laboratory analyses based on approved methods such as American Standard Test Method (ASTM) D-1949.

- Aside from the questionable CO measurements, the other data collected by the automatic monitoring system are accurate and compare well with laboratory results. These data are essential for managing and evaluating system operation.

- GPR has proven to be the best tool for monitoring moisture movement in both the cover soil and refuse. The other moisture monitoring methods provide information of limited value.

- The most effective air delivery pattern may be the alternating one used during the last two months of this phase of the pilot test. Preliminary results have shown that the air injection and extraction rates can be as low as one quarter of the original estimate, while still maintaining aerobic conditions and controlling subsurface temperatures.

- If temperature control using water application becomes difficult, air flow patterns and flow rates can be altered to maintain temperatures in the optimal range.

- Surface settlement on the order of 4% of the total refuse thickness has been measured inside the test plot. Volume removal both inside and outside the test plot, over an area with a radius of 75 ft, is occurring at a rate of approximately 61 ft^3 per day.

- No compounds have been detected in soil gas and water samples at levels that are cause for environmental concern.

The actions listed below are proposed for the remainder of the Nearmont pilot test, as well as for future sites, to improve the understanding and design of the aerobic landfill stabilization process:

- Increase subsurface moisture contents above those levels achieved to date at Nearmont by increasing the water application rate. Increased moisture contents may increase biodegradation rates. In addition, continue to evaluate the best water application method that will reduce water lost as evaporation during the summer months.

- Raise the operating temperature to 180°F, to provide enough flexibility to allow optimal temperatures, and therefore optimal degradation rates, to be achieved.

- Develop a closure plan.

- Improve refuse sampling methods to ensure more representative samples are collected.

- Eliminate the use of field CO meters. CO concentrations should be determined by laboratory analyses of soil gas samples.

- Establish a survey system that is more comprehensive than the one currently being used at Nearmont.

- Construct air circulation wells so that they can act as either an extraction or injection well.

- Resolve inconsistencies between empirical air circulation requirement for temperature control and theoretical requirements based on energy balance calculations.

If you have any questions or require additional information, please feel free to contact Jinshan Tang at (520) 293-1500, extension 118.

Prepared By:	Reviewed By:
Leslie Major, M.S. Staff Hydrologist	Gary Walter, R.G., Ph.D. President
Jinshan Tang, M.S., P.E. Project Manager	

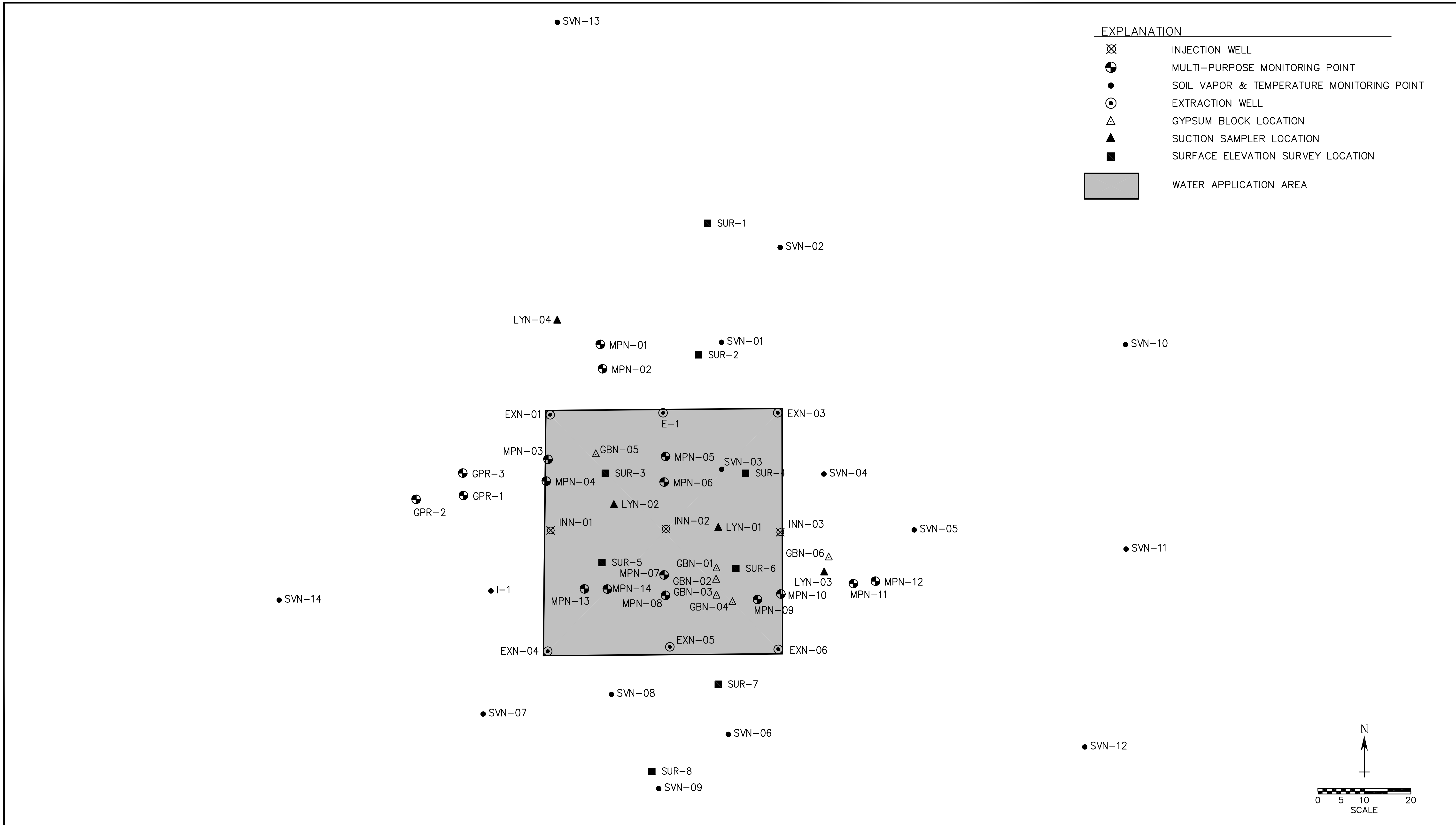
Attachments

ATTACHMENTS

FIGURES

1 Pilot Test Monitoring Locations
2 Nearmont Air Circulation Data, Total Air Injection and Extraction Rates
3 Nearmont Borehole GPR Data, MPN-3 and MPN-4
4 Nearmont Temperature Data, 20-Foot Probes Since Start of Air Circulation
5 Nearmont Soil Gas Data, 24-Hour Running Average Extraction Well EXN-03
6 Nearmont Land Surface Settlement Data

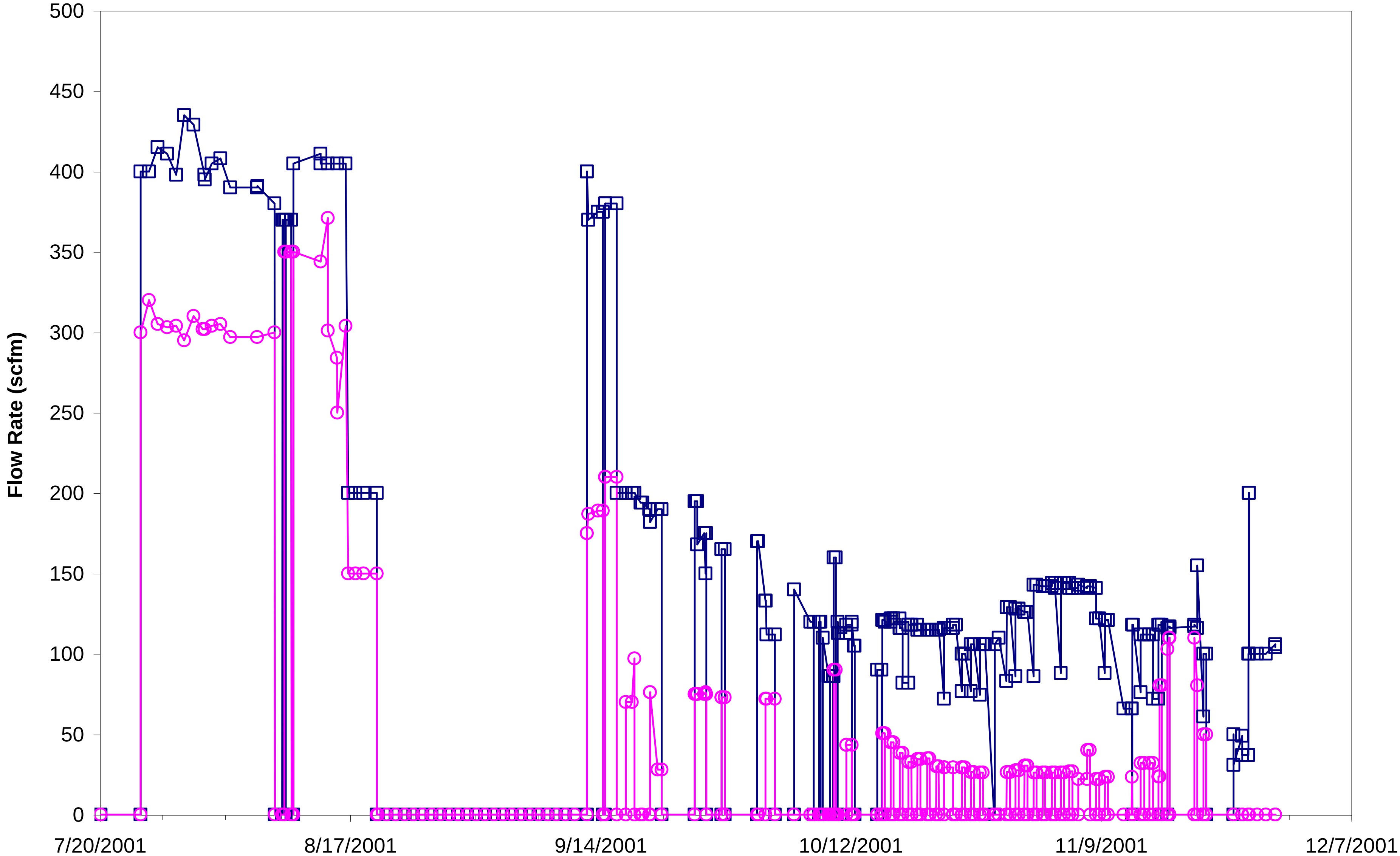
FIGURES



HYDRO GEO CHEM, INC.

PILOT TEST MONITORING LOCATIONS
RIO NUEVO LANDFILL STABILIZATION PILOT TEST

Approved	Date	Revised	Date	Reference:	FIG.
LM	10/24/01			74507007	1

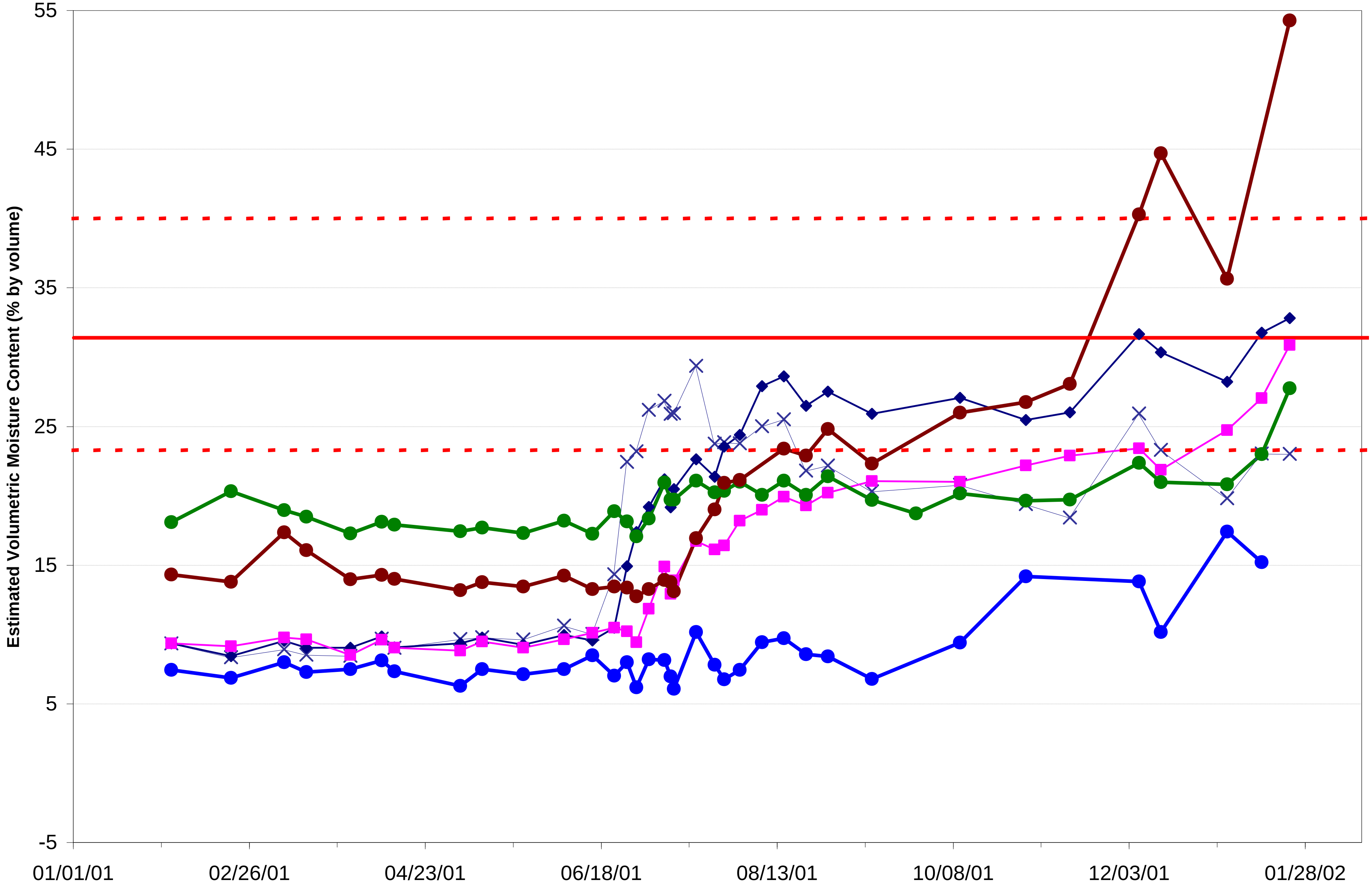


EXPLANATION

extraction injection

HYDRO GEO CHEM, INC.

NEARMONT AIR CIRCULATION DATA TOTAL AIR INJECTION AND AIR EXTRACTION RATES RIO NUEVO LANDFILL STABILIZATION PILOT TEST			
APPROVED LAM	DATE 12/12/01	REFERENCE H:\74500\74507\Reports\Summary_2\RN_P2_summ2_flowrates.xls	FIGURE 2



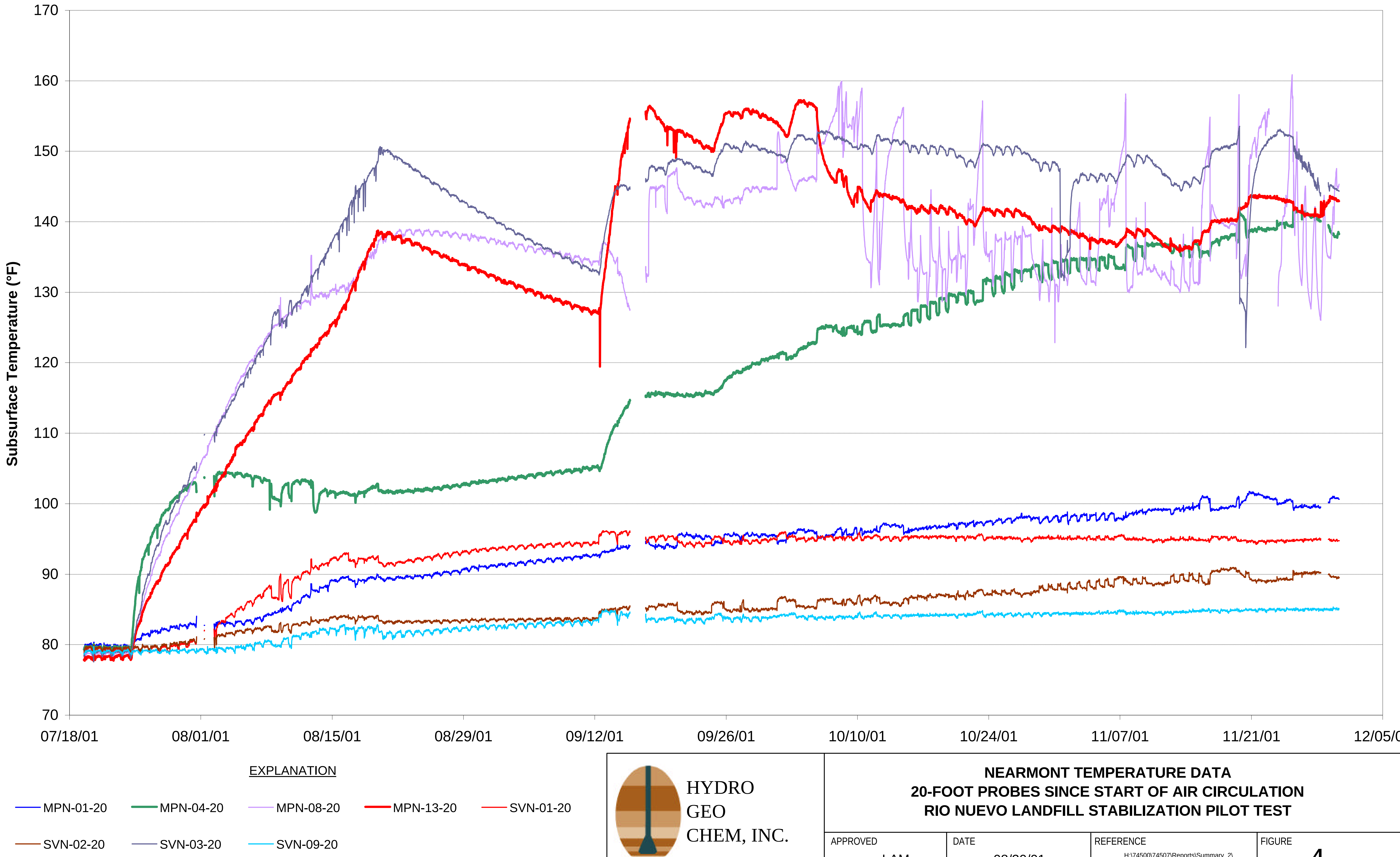
EXPLANATION

- 4.30 ft below surface
- 6.76 ft below surface
- 9.22 ft below surface
- 11.68 ft below surface
- 25.62 ft below surface
- 30.55 ft below surface
- target MC (55% by wt)
- lower MC limit
- upper MC limit

HYDRO
GEO
CHEM, INC.

NEARMONT BOREHOLE GPR DATA
MPN-3 AND MPN-4
RIO NUEVO LANDFILL STABILIZATION PILOT TEST

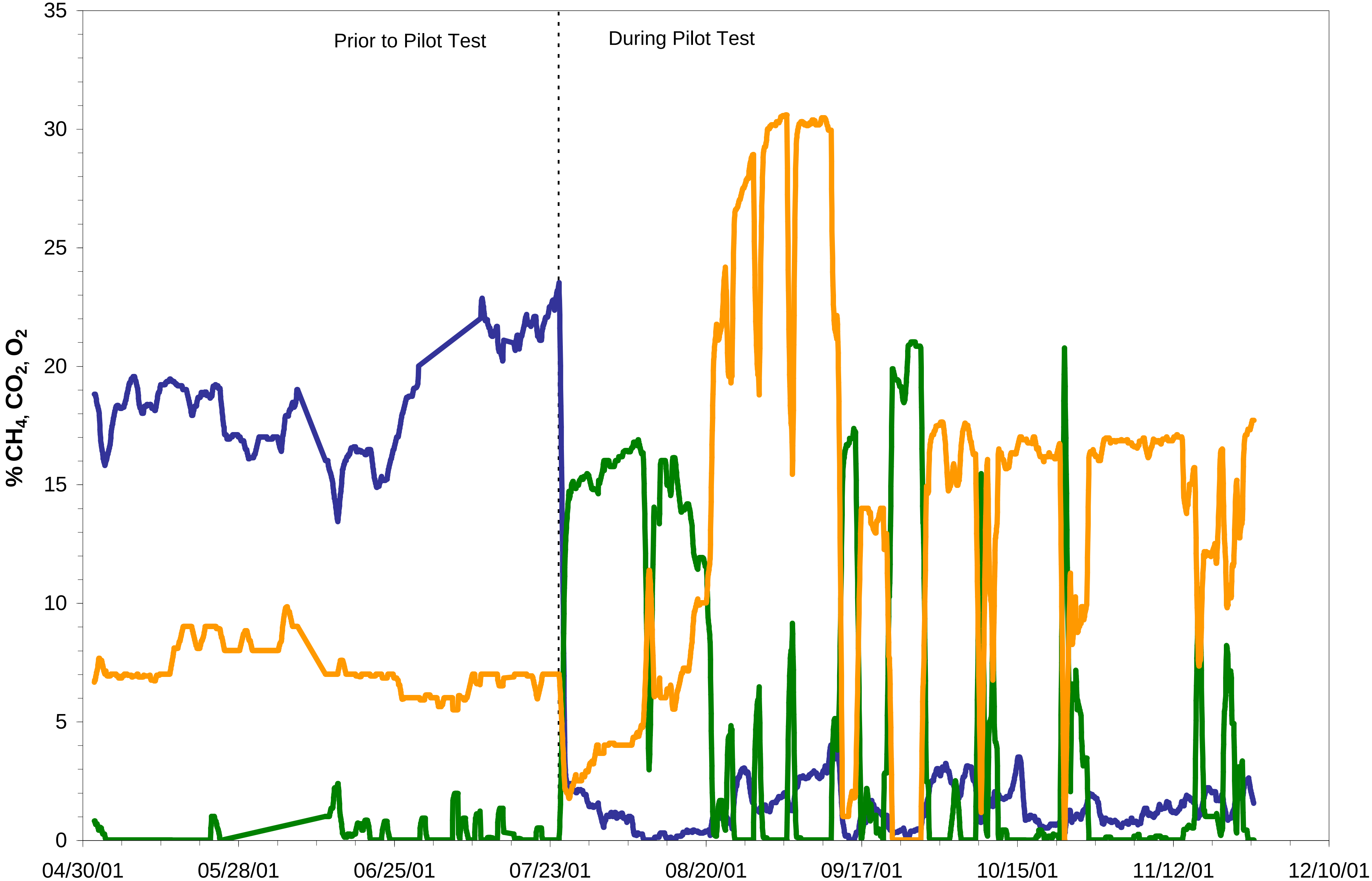
APPROVED	DATE	REFERENCE	FIGURE
LAM	6/30/01	H:\74500\74506\Moisture\Nearmont_MC_gravcalcs.xls	3



HYDRO GEO CHEM, INC.

NEARMONT TEMPERATURE DATA
20-FOOT PROBES SINCE START OF AIR CIRCULATION
RIO NUEVO LANDFILL STABILIZATION PILOT TEST

APPROVED	DATE	REFERENCE	FIGURE
LAM	08/30/01	H:\74500\74507\Reports\Summary_2\ RNP2_summ2_temperatures.xls	4



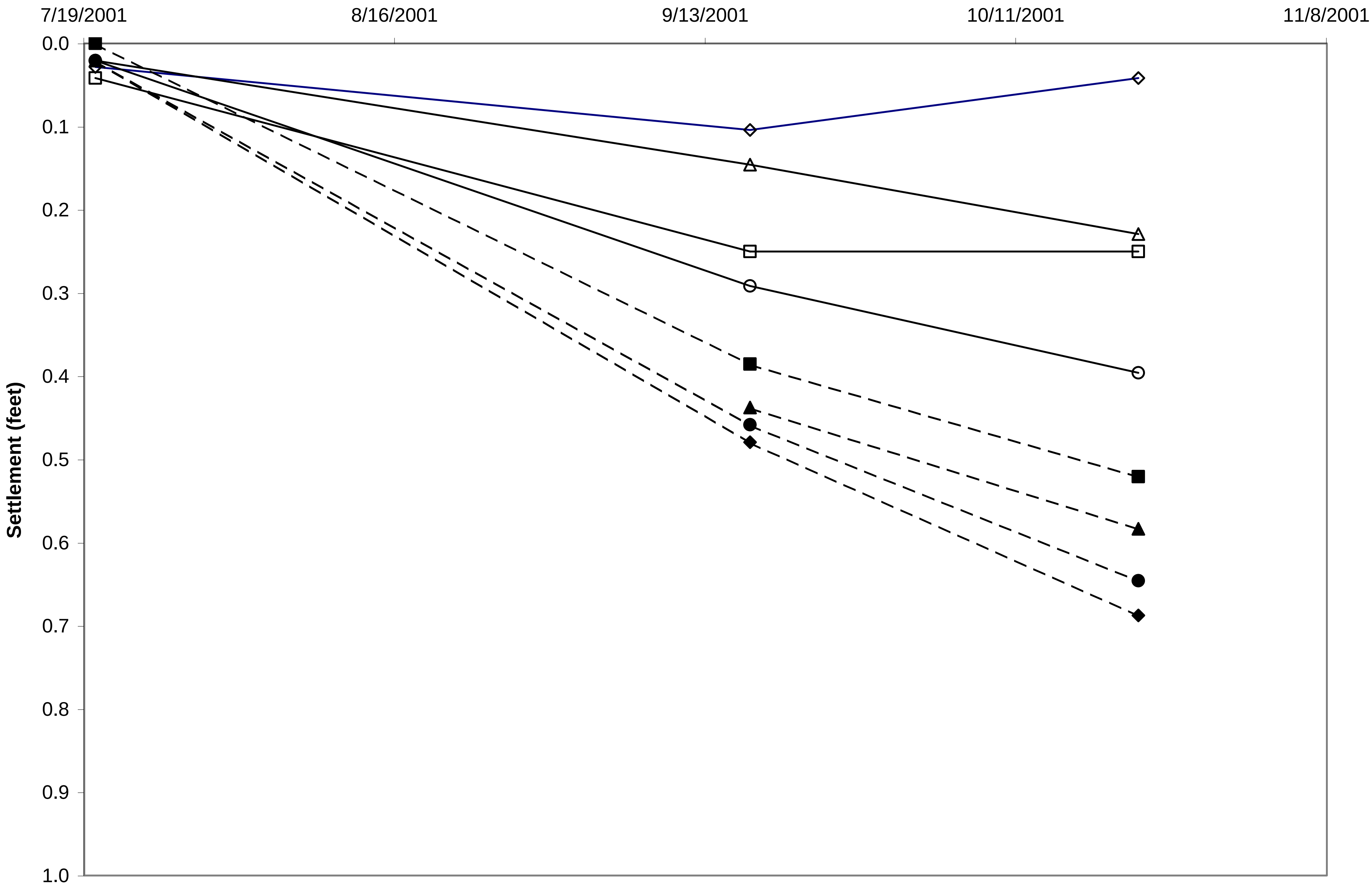
EXPLANATION

- - - - - - Start of Pilot Test
EXN-03 CH4 avg
EXN-03 O2 avg
EXN-03 CO2 avg

HYDRO GEO CHEM, INC.

NEARMONT SOIL GAS DATA
24-HOUR RUNNING AVERAGE
EXTRACTION WELL EXN-03
RIO NUEVO LANDFILL STABILIZATION PILOT TEST

APPROVED	DATE	REFERENCE	FIGURE
LAM	12/12/01	H:\74500\74507\Reports\Summary_2\ Summ2_SoilGasPlots_ALL.xls	**5**



EXPLANATION

SUR-1 SUR-2 SUR-3 SUR-4

SUR-5 SUR-6 SUR-7 SUR-8

HYDRO
GEO
CHEM, INC.

NEARMONT LAND SURFACE SETTLEMENT DATA
RIO NUEVO LANDFILL STABILIZATION PILOT TEST

APPROVED	DATE	REFERENCE	FIGURE
LAM	10/05/01	H:\745000\74507\Reports\Summary_2\RNP2_summ2_settlement.xls	6